THE TURBOSUPERCHARGER

Answer to High Altitude Flight

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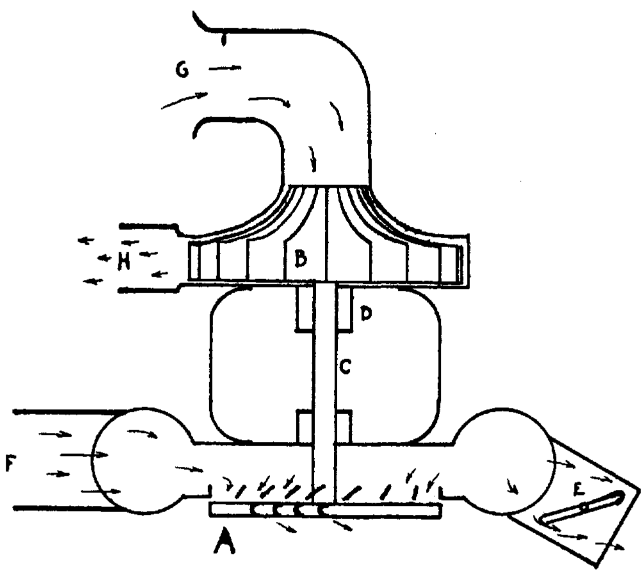
THE EXCELLENT PERFORMANCE and ingenuity of design embodied in American military aircraft is the major factor in contributing to our success over enemy aircraft. One of the major achievements in this field of design is the American-made turbosupercharger, T.S. Although many persons have been instrumental in the development and success of the T.S., the name of Dr. Sanford A. Moss stands foremost on the list.

Dr. Moss was born in San Francisco on Aug. 23 in 1872. Boyhood service in a San Francisco machine shop which made air compressors for mine work outfited Dr. Moss with the necessary information on problems dealing with air pressure. In this period, he first became interested in doing things with air and assimilated knowledge of mechanical tricks which in later years gave him advantages in competition with scientists whose theoretical knowledge was insufficient to handle the problem of air and gases moving with the power of a tornado.

Why did the need arise for a T.S.? The answer lies in the simple fact that engines, like humans, require a constant normal supply of air with which to function at peak performance. Since air is our criteria, let us examine its function and its distribution above the earth's surface. An aircraft engine derives its power from the combustion of its fuel with air. In fact, approximately 14 pounds of air is required for each pound of fuel. A 2000 Hp. engine in normal flight consumes 8 tons of air in one hour.

It should be noted that weight, not volume, is of major importance. The horsepower derived from each firing stroke depends primarily on the compression ratio of the engine and the weight of the charge of fuel. The compression ratio being fixed in any particular engine leaves the *weight of charge* the only variable affecting the horsepower of the engine. The weight of fuel mixture, and incidently the horsepower of the engine, depends on the temperature and pressure at which this mixture enters the cylinders. The ratio between the weight of the charge inside the cylinder at the end of the intake stroke to its weight, if it were at atmospheric temperature and pressure, is called the volumetric efficiency. Prior to the invention of the supercharger, volumetric efficiencies were restricted to 75-85 per cent. This imperfect result was due to frictional obstructions in the parts and ducts of the engine itself as well as the decrease in density due to the expansion of a charge while traveling over *hot* engine structures.



Turbosupercharger

M. Robison

A—Turbo Bucket Wheel
B—Compressor Blades
C—Short Shaft
D—Bearings
F—Engine Exhaust
G—Ram Air Intake
H—Compressed Air to Engine

It is a well known fact that an increase in altitude is attendant with a decrease in air density, i.e., the air gets thinner, or the mass of air per given space is greatly decreased. When a fighter pilot of a high altitude air craft reaches a critical altitude, 12,000 feet, at which he requires additional oxygen, he has but to open the valve of his nearby oxygen supply and receive the necessary air for normal functioning. But what of the aircraft engine? At this altitude the engine, also lacking the necessary air, shows a decrease in performance by its inability to maintain air speed and by its lack of reserve power for fighting needs.

Here the T.S. is to the engine as the pilot's oxygen supply is to his human body. The exact function of supercharging is the precompression of the atmospheric air before admission to the engine for the purpose of maintaining constant sea-level density in the "lungs" of the engine, and with it, full engine power.

To accomplish this precompression, two major applications of the basic principle have been developed. It is our purpose to make a study of the Turbosupercharger in high altitude flight and briefly point out it advantages over the geared type of supercharger.

The Turbosupercharger consists of a turbine wheel, upon which hot exhaust particles from the engine strike, causing rapid rotation. This is similar to the derivation of mechanical power from a water wheel. The rotating turbine is connected by a short shaft to a centrifugal air compressor similar to the blower in a household vacuum cleaner. The shaft is supported by two bearings between the blower and turbine. About the shaft and bearings is a lubrication unit which supplies oil to the blower bearing operating at approximately —67°F and also to the turbine bearing at 1500°F. This problem of operating beams at such extreme temperature differences was solved by typical Yankee ingenuity and is the prime advantage of our supercharger over all others. Furthermore, this achievement enables the American unit to operate for 500 flying hours, whereas previous allied units were good for merely 50 hours. Not only did we use new and different metals in our bearing mixtures but also special heat treatments which are secret and unknown even to our allies.

Considering the amazing effectiveness and simplicity of the T.S., an effort will be made to illustrate how closely allied its functions are to simple, basic physical principles.

The cycle of operation of the supercharger is as follows: Hot exhaust gases leave the engine at high speed at a temperature of 1500°F. The fast moving molecules of the gas enter the nozzle box and are directed against the turbine buckets causing the turbine to rotate at a speed of 7000 to 21,000 r.p.m. This in turn spins the shaft and blower increasing the pressure of the outside air to atmospheric or greater pressure. This increase in pressure is accompanied by the usual increase in temperature, and since no heat is lost it is said to be adiabatic compression. Since an increase in temperature allows the gas to expand and lower its density some means must be provided to reduce the temperature so that a normal weight of charge may be maintained. To provide this cooling, an intercooler or radiator is placed in the stream of compressed air. The intercooler acts similarly to an automobile radiator except that air flows through the radiator in place of water. The intercooler receives its cooling air from a ram air intake located in the leading edge of a wing or nacelle of the craft.

Leaving the intercooler, the air is carried in ducts to the engine carburetor where it picks up its fuel charge and enters the internal blower and receives an extra boost. It is interesting to note here the development of this blower or internal supercharger. Original design intended the blower as a device for distributing the fuel mixture evenly to all the radially placed cylinders. However, after experimentation it was noted that the blower or diffuser not only distributed the gases as was planned, but also increased the actual weight of charge raising the volumetric efficiency to greater than 100 per cent. From this revelation evolved the present day two-speed geared supercharger. With this additional boost the charge enters the cylinders, is burned during the firing stroke and is discharged into the exhaust pipe where it completes the cycle.

The main purpose of supercharging is maintaining sea-level pressure in the intake manifold. If the rotor were to revolve at a constant high speed oversupercharging would result at sea-level and damage to engine parts would result. To accomplish a gradient rotor speed with increase in altitude, the supercharger nozzle box is equipped with an exhaust port or waste gate. The function of this gate is to let out some of the exhaust gases, preventing them from spinning the rotor. By manually controlling the gate and by observing his manifold pressure gage, the pilot can maintain the proper degree of supercharging. Because of electronic advancement, automatic control of the manifold pressure has been accomplished.

Oddly enough a physical phenomenon aids the supercharger in supplying the necessary air. Assuming a constant engine exhaust output for a small increase in altitude, there is a decrease in atmosphere pressure. This lowering of pressure on the outboard side of the turbine wheel increases the pressure difference between nozzle box and atmosphere, which results in increased gas velocity, spinning the compressor faster and compensating in some measure for the decrease in air density.

Throughout, it has been assumed that the war-conscious reader has realized the many advantages to high altitude flying. Aside from the very good reasons for high altitude flying in war time such as escape from flak, increased accuracy in

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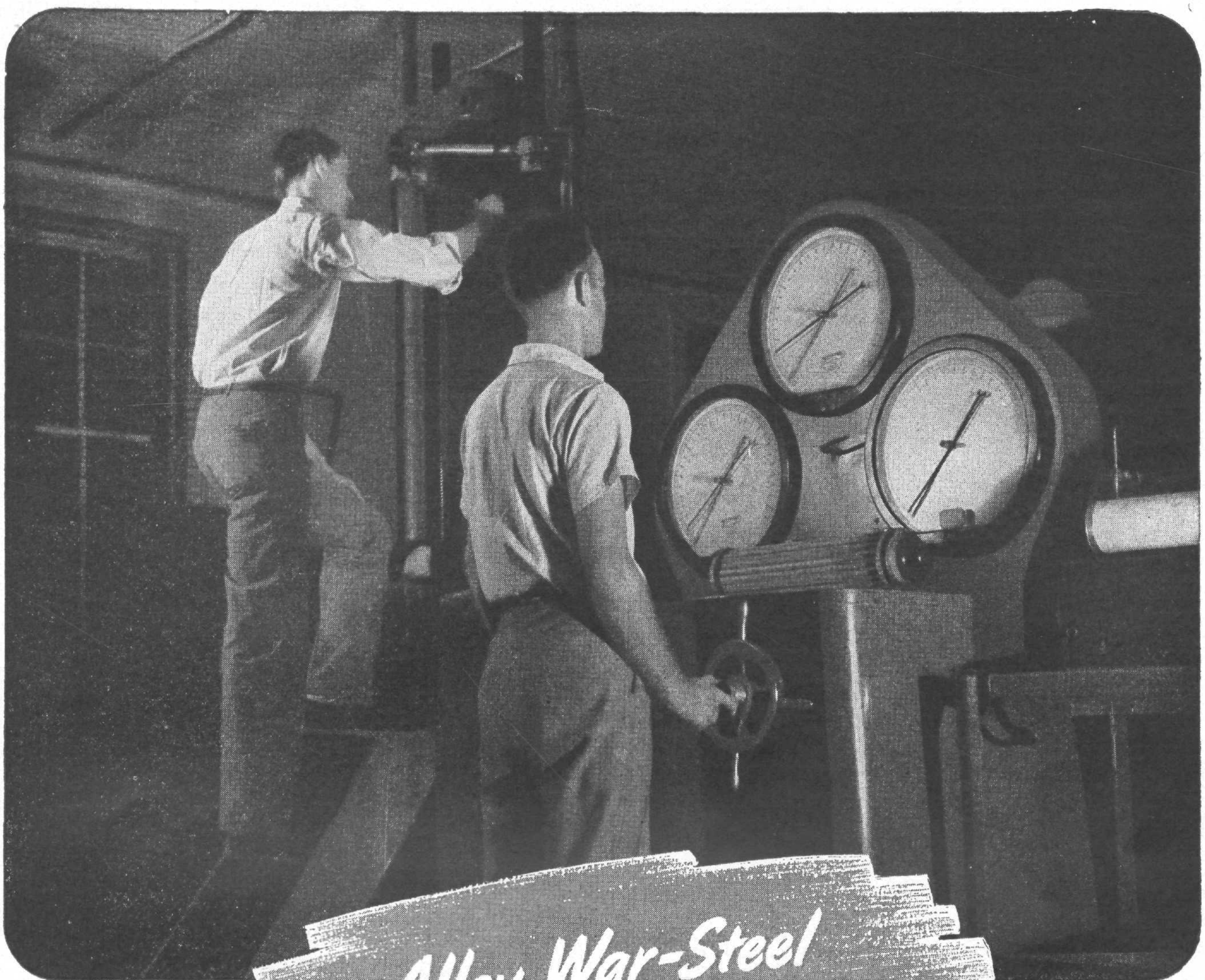
bombing, and elimination of weather hazards, there are as many good peacetime advantages. In stratosphere flying one can look forward to smoother, faster and safer flying. At high altitude, the lower air density reduces drag on the ship; in fact, the airplane gains roughly 1 per cent of airspeed for every 1000 ft. increase in altitude. High speeds mean less fuel. Hazards such as storms, and wing and engine icing are completely left behind when the craft reaches the stratosphere. Winds are steady and gradient, a headwind may be avoided by a change in altitude.

The intricacies of the T.S. were not perfected without extensive research in overcoming the many engineering problems. The early history is marked with many record breaking flights culminating in an ascent of 56,000 feet in Italy in 1938.

Undoubtedly of major historical consequence was a performance test before Army Air Corps officials on Pike's Peak of the Turbo-supercharger mounted on a Liberty engine. The engine was rated at 350 H.P. at McCook Field, Dayton, Ohio, an elevation of approximately 500 feet above sea level. When taken to Pike's Peak, 14,190 feet, the engine produced only 230 H.P. a decrease in power of nearly 30 per cent. Equipped with a supercharger, however, the engine not only produced its rated 350 H.P. but also an excess of 6 H.P. This won the approval of the army engineers to the practicality of the supercharger.

Although high altitude flight is far from its infancy stage the Turbosupercharger will prove to be the leading cog in its further development.



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OWI Photo by Palmer, in an Allegheny Ludlum Plant

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